Status of ATLAS commissioning

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Sandro Palestini, CERN
for the ATLAS Collaboration

Talk presented on behalf of the ATLAS Collaboration

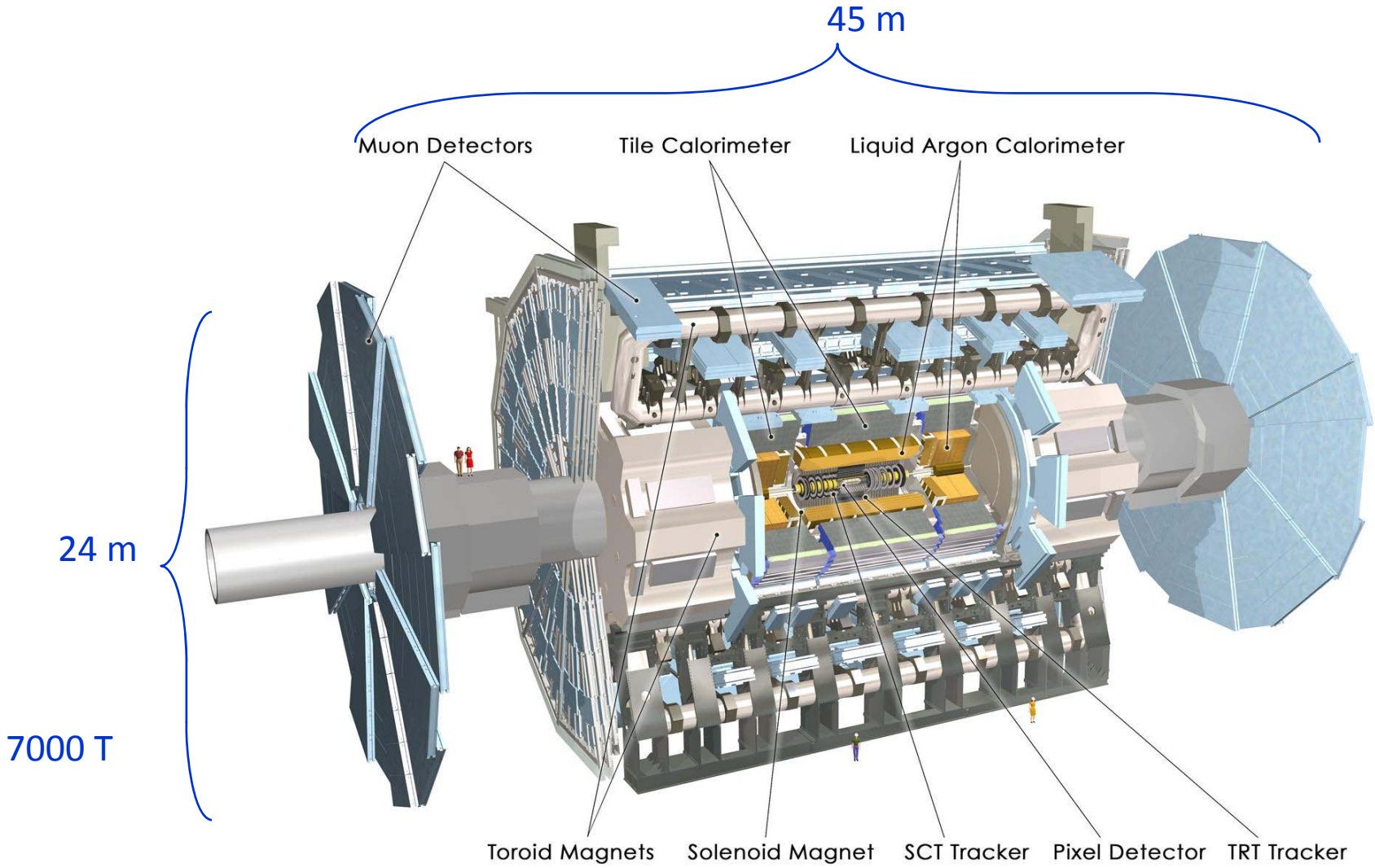
37 Countries
169 Institutions
2500 Scientific Authors total

Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Chile,Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford,Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Ritsumeikan, UFRJ Rio de Janeiro, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

Outline

- Last phases of detector installation
- Tests of full magnet system
- Detector commissioning
- Combined cosmic runs
- DAQ/data flow
- Commissioning of computing model
- Preparation of physics studies
- Experience with first beams on Sept. 10

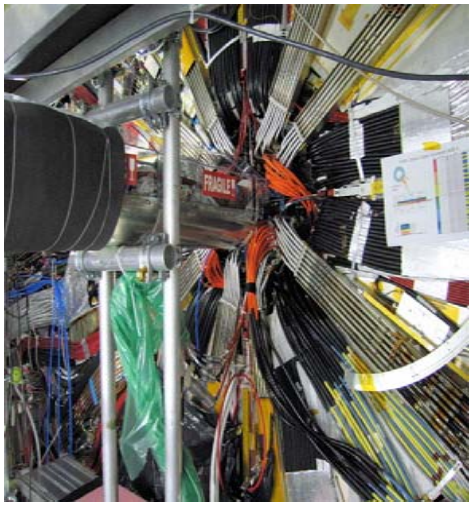
The ATLAS detector



Ref.: “The ATLAS Experiment at the CERN LHC”, 2008 JINST 3 S08003 (http://www.iop.org/EJ/toc/1748-0221/3/08)

Installation of the last components

Installation of Small Wheels of Muon End-Cap in Feb-Mar 08

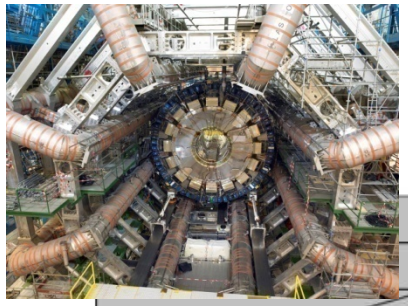


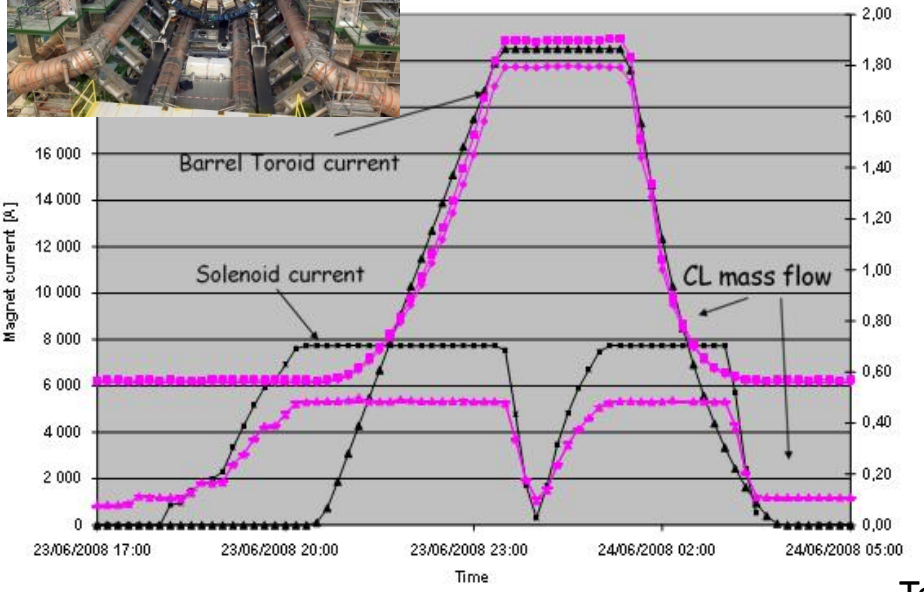
Cabling of Pixel detector in spring 08

Completion of outer station of Muon End-Cap in June 08

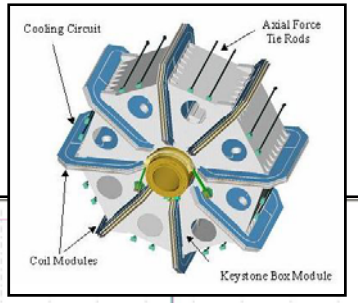
LHC beam-pipe closed in June 08

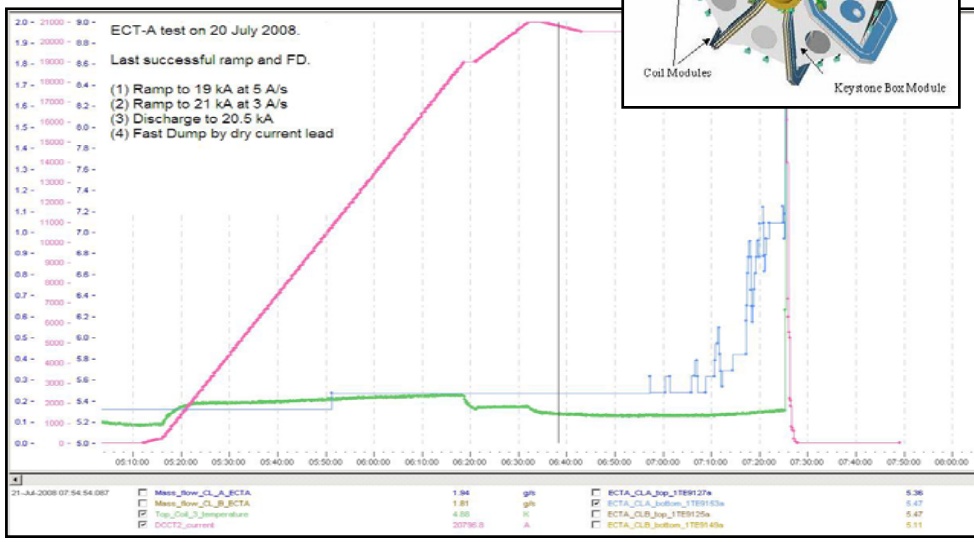
Test of the full magnet system



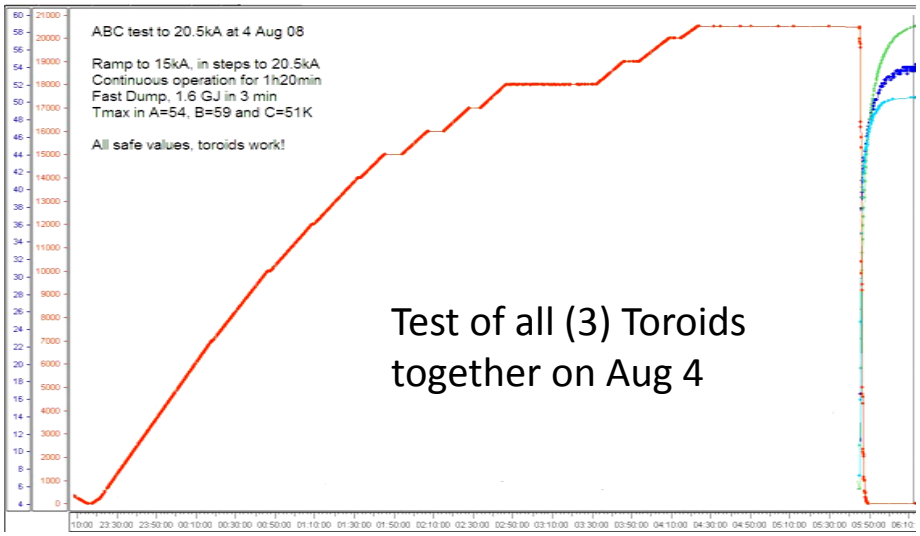


Test of Barrel Toroid and Solenoid on July 23-24

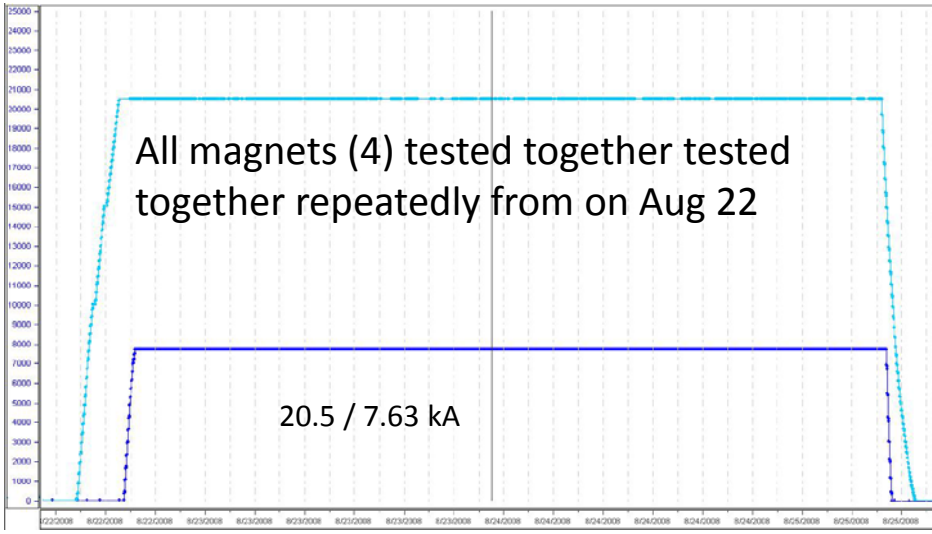




Test of End-Cap Toroid side A on July 20 (after leak repair)



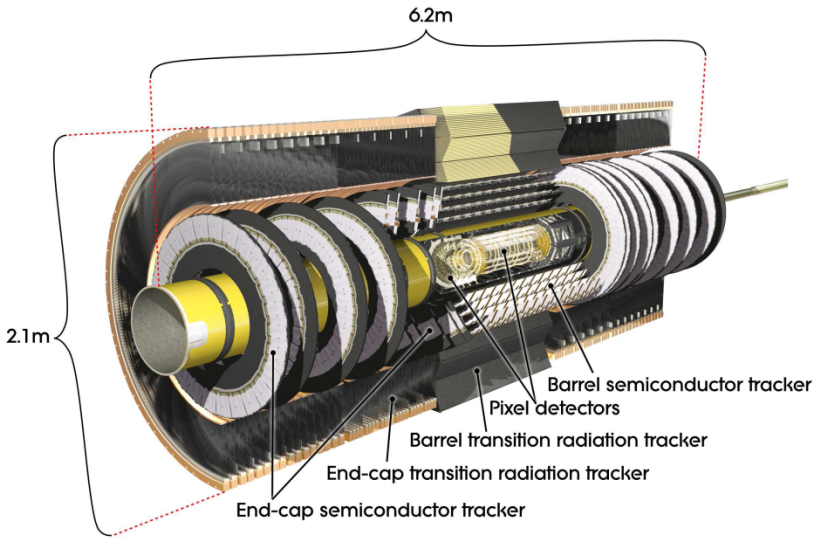
Test of all (3) Toroids together on Aug 4



Detector commissioning

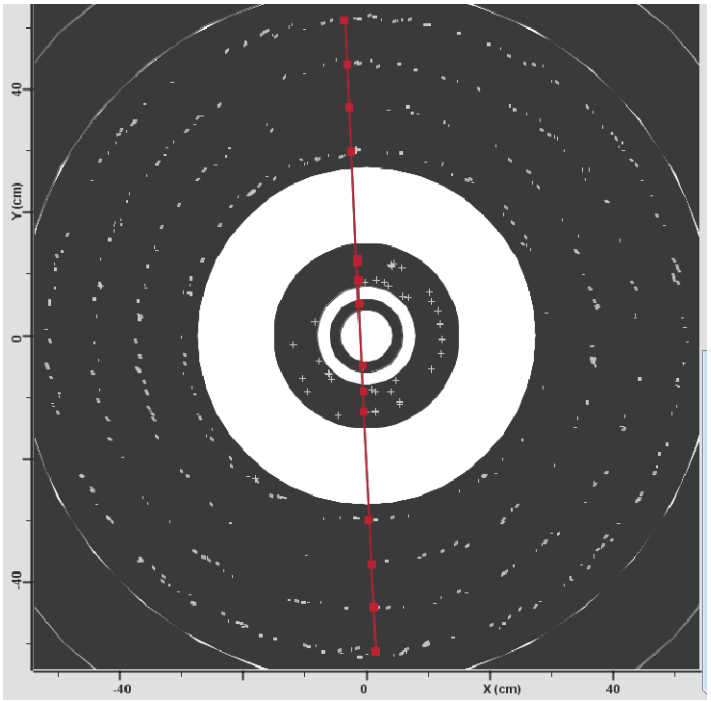
- The commissioning of the detector started in 2006 with the first Milestone Run and Technical Runs:
  - Operate together the various subsystems (with local and central Detector Control System), verify stability of hardware
  - Develop and test data monitoring
  - Check channel mapping, noise, timing
  - Integrate into DAQ
  - Commission and operate trigger systems (cosmic rays)
  - Develop and test calibration procedures
  - Acquire and process data, make first test of track-based calibration and alignment

Inner Detector



Status of commissioning:

- Pixel delayed by difficulties with cooling, could only start in August after beam-pipe bake-out
- Currently 94 % of the module are active
- Cosmic ray tracks have been detected together with SCT from mid-September.

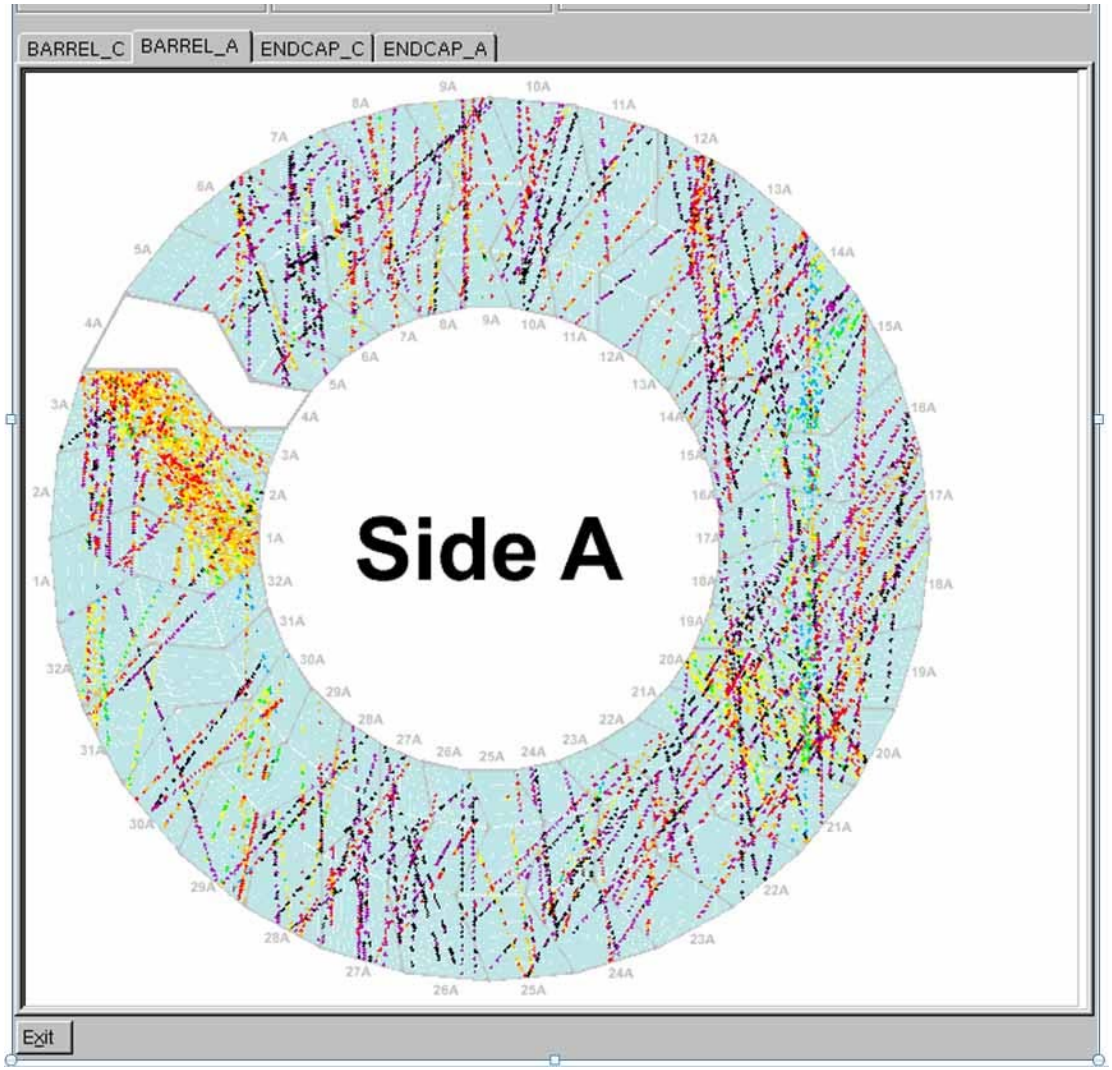


6+1 points in Pixel, 8 points in SCT

Design and goals:

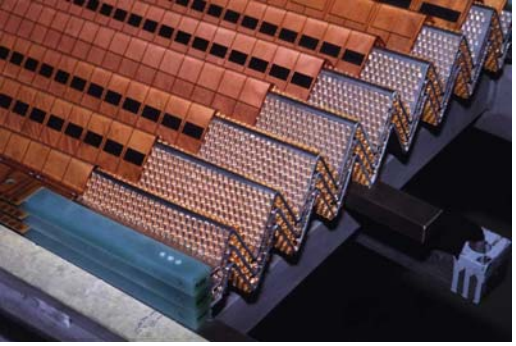
- Si pixels, Si strips , straw tubes, $|\eta|<2.5$ (<2 TRT)
  - Pixel: 80 M channels, 3 layers
  - SCT: 8 layers, stereo pairs, 6.3 M ch.
  - TRT: 350 k ch., typically 36 hits/track, transition radiation (e/π: 0.5-150 GeV)
- Operate in 2 T solenoid field
- $\sigma\ p_T/p_T \sim 0.05\%\ p_T \oplus 1\%$

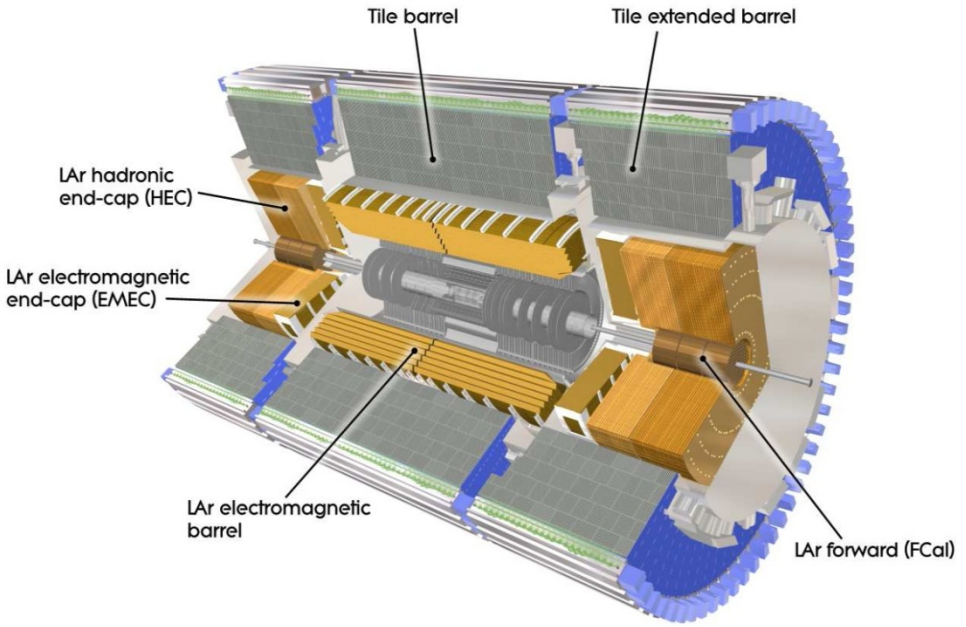
TRT commissioning



Hit map (many events) in TRT/barrel , projected to z = 0, from cosmic-ray run in June 08.
Color maps different track time (within ± 35 ns, due different triggering devices).

Calorimeters





Design:

"Barrel" calorimeters

- Electromagnetic: $|\eta|<3.2$
  - Lead-liquid argon, 3 sampling depths in precision region $|\eta|<2.5$; Presampler $|\eta|<1.8$
  - ~175k channels
- Hadronic:
  - Barrel: steel-scintillating tiles $|\eta|<1.7$, 3 sampling depths, 10k channels
- Endcap: $1.5<|\eta|<3.2$,
  - copper-liquid Ar, 4 sampling depths, 6k channels
- Forward: $3.1<|\eta|<4.9$
  - (1 Copper+2 tungsten)-liquid Ar depths for e.m. and hadronic measurements, 3.5k channels

Goals:

precision measurements of e/γ for $|\eta|<2.5$

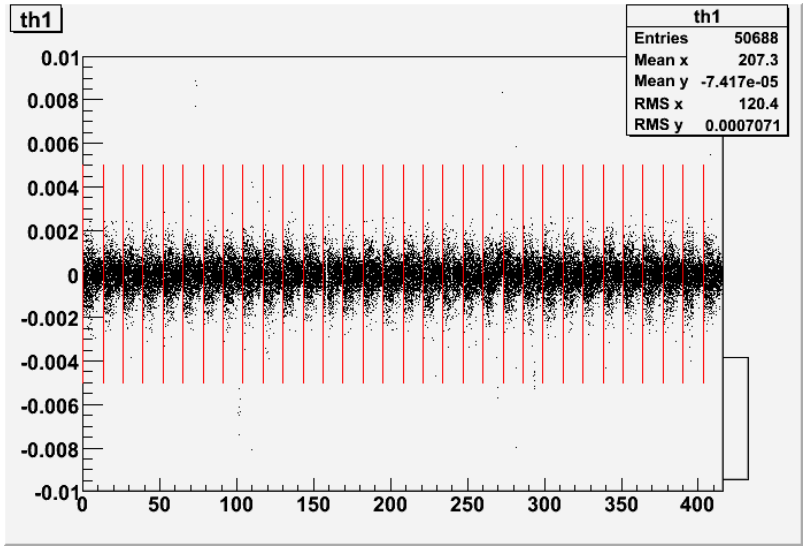
- $\sigma/E \sim 10\%/\sqrt{E} \oplus 0.7\%$
- Linearity to ~0.1%

Coarser granularity in the forward region

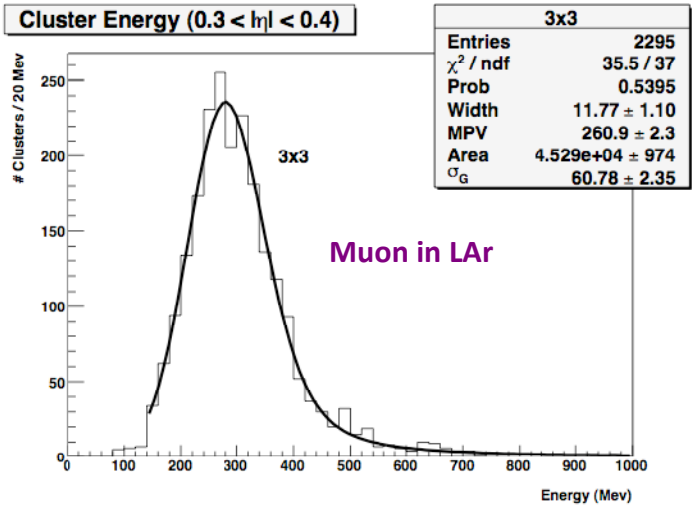
Total energy resolution for Jet and E_T^{miss} measurements

- $\sigma/E \sim 50\%/\sqrt{E} \oplus 3\%$ (barrel/endcap)
- $\sigma/E \sim 100\%/\sqrt{E} \oplus 10\%$ (forward)

Calorimeters commissioning

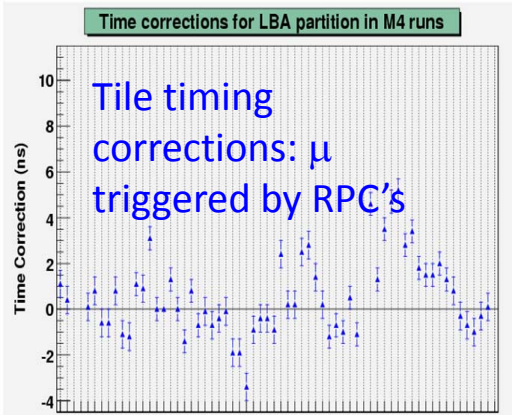


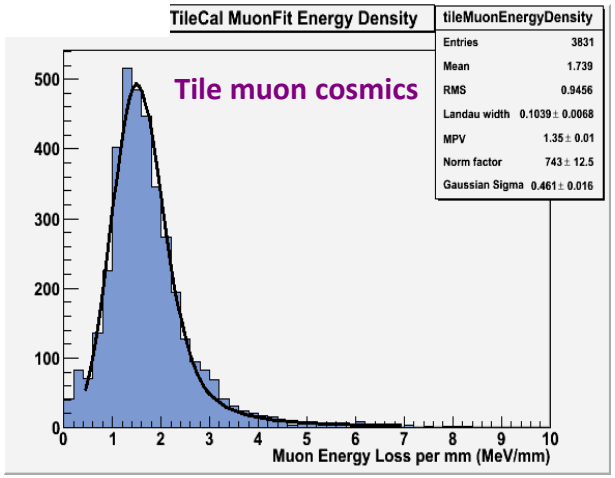
Stability LAr Barrel side A:
Difference of amplitude between two calibration runs taken one week apart vs. channel number (14*32 FEB - 128 channels each)



Muons in calorimeters: energy scale and uniformity verified at ~2 %

- LAr dead/noisy channels:
  - Dead channels:
    - EMB: 0.5%, EMEC: 0.2%, HEC (15%), FCAL (0%)
  - Noisy channels:
    - > 10σ w.r.t. ϕ average: 0.003%
    - Between 5σ and 10σ: 0.09%
  - Uncalibrated or badly calibrated channels: 0.3 / 0.2 %
  - Most problems recoverable during a shutdown (exchange of FEB)





Muon Spectrometer

Air-core toroid magnet system

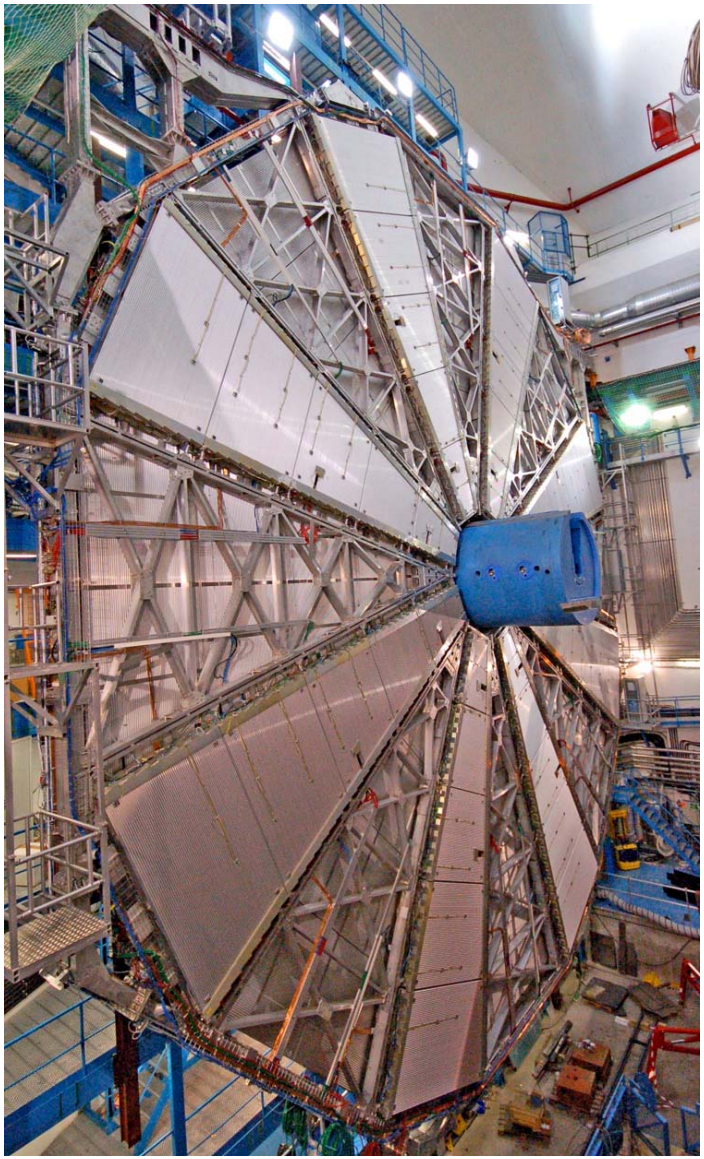
- Barrel: ~1.5-5.5 Tm in $0<|\eta|<1.4$
- Endcaps: ~1-7.5 Tm in $1.6<|\eta|<2.7$

Precision tracking chambers

- Track coordinate in bending plane
- 3 barrel layers, 3 end-cap wheels
- ~370k readout channels
- Monitored Drift Tubes (MDT)
  - $|\eta|<2.7$ (innermost layer $|\eta|<2.0$)
- Cathode Strip Chambers (CSC)
  - innermost layer $2.0<|\eta|<2.7$

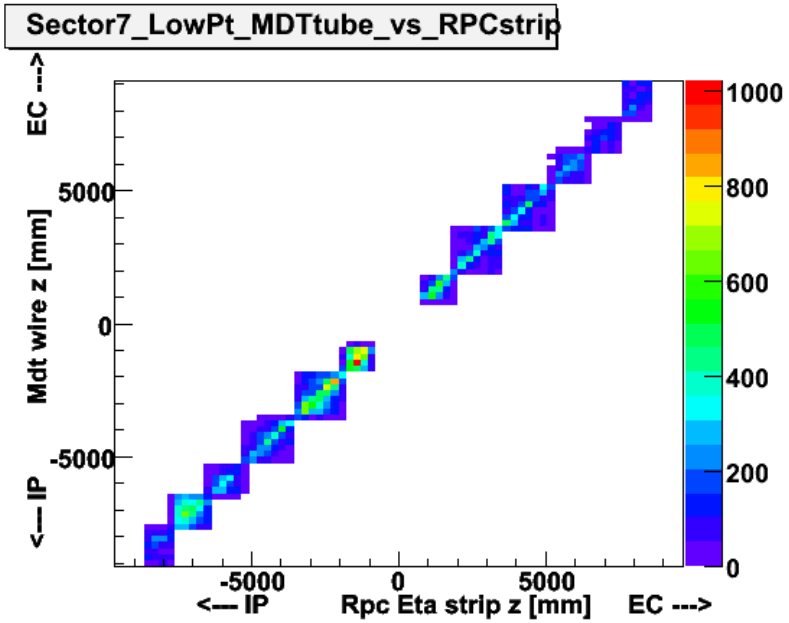
Trigger chambers

- Bunch-crossing ID, triggering, coordinate orthogonal to tracking measurement
- ~680k readout channels
- Resistive Plate Chambers (RPC)
  - $|\eta|<1.05$
  - 3 double layers
- Thin Gap Chambers (TGC) (4+4 wheels)
  - $1.05<|\eta|<2.7$ (2.4 for triggering)



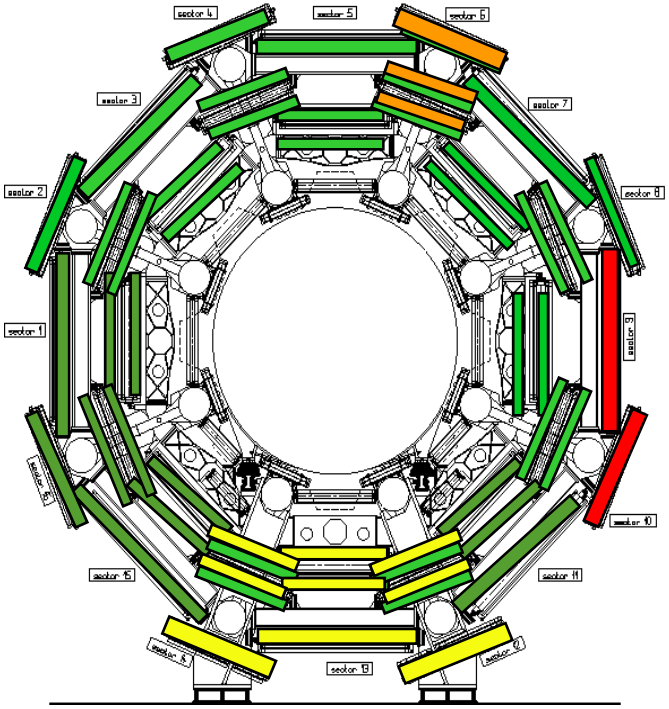
MDT Big Wheel (Intermediate EndCap station) during installation

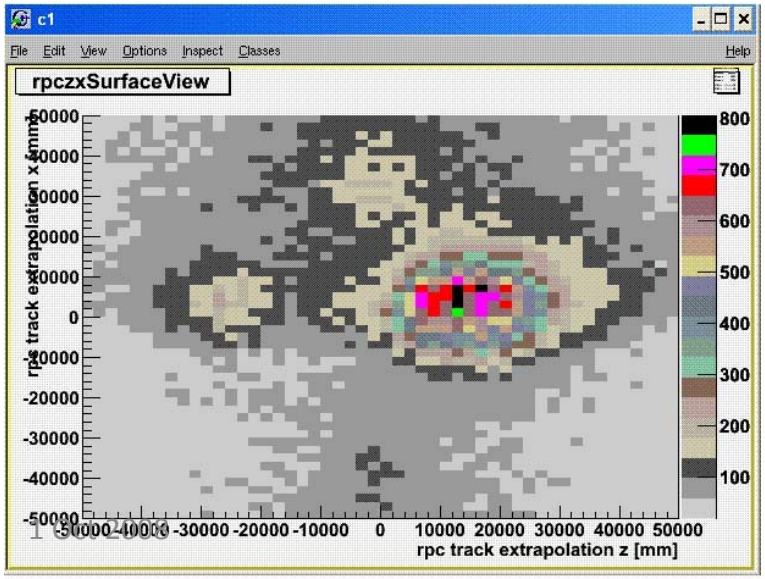
Muon spectrometer commissioning



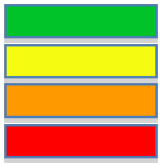
Correlation between MDT and RPC hits in cosmic data

Commissioning of RPC sectors



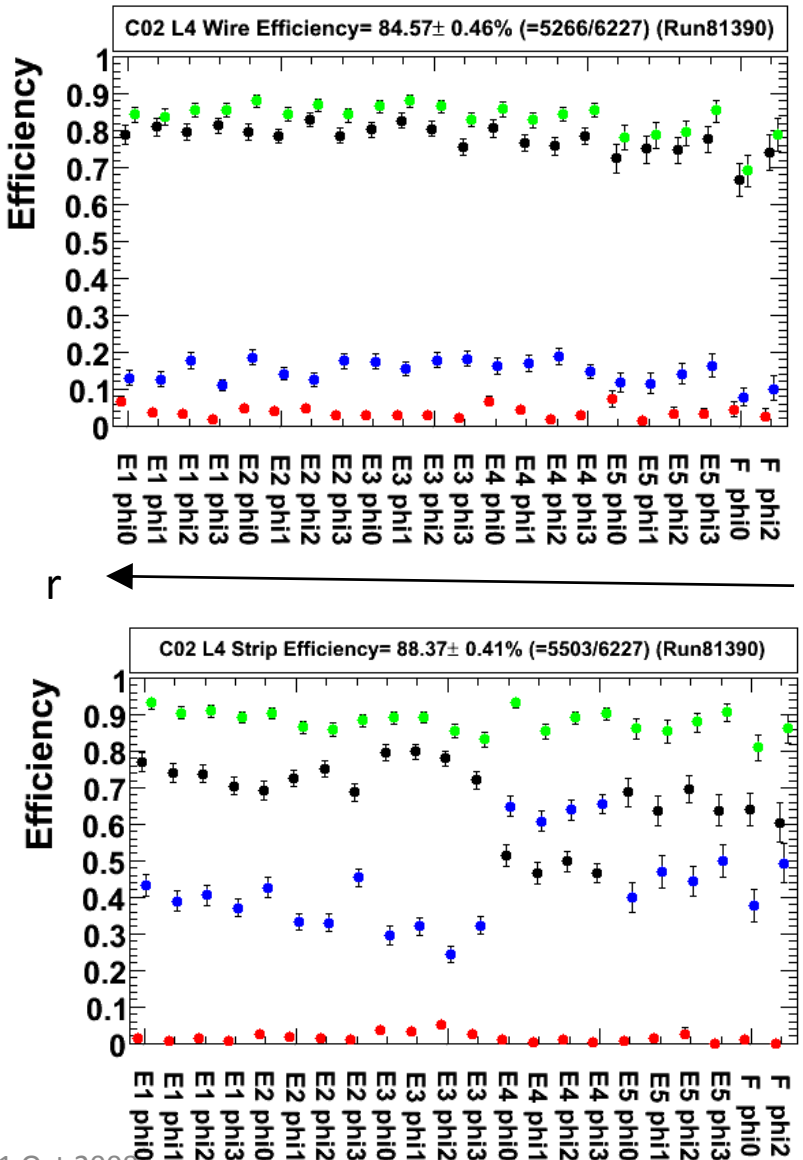


track projections from RPCs to surface



Ready
Missing timing adjustment
Noise on clock propagation
Missing CAEN boards

TGC chambers

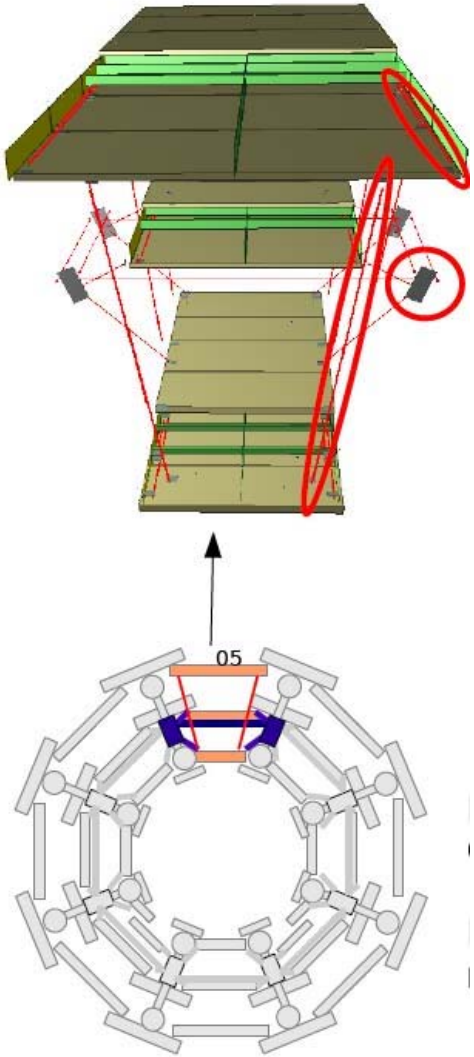


Flammable gas system allowed only since July 2008: very low efficiency before that time. Studies of efficiency (and timing) started recently and are still underway.

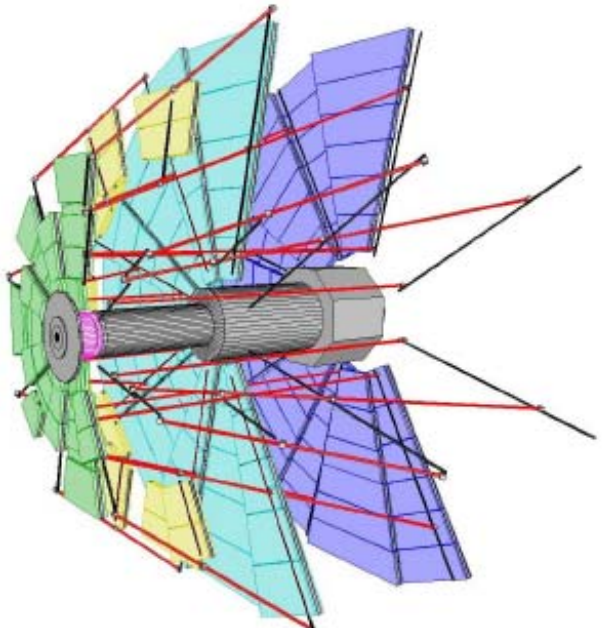
Efficiency with hits at “current” or “next” bunch-crossing:

Red : Previous
Black : Current
Blue : Next
Green : Current or next

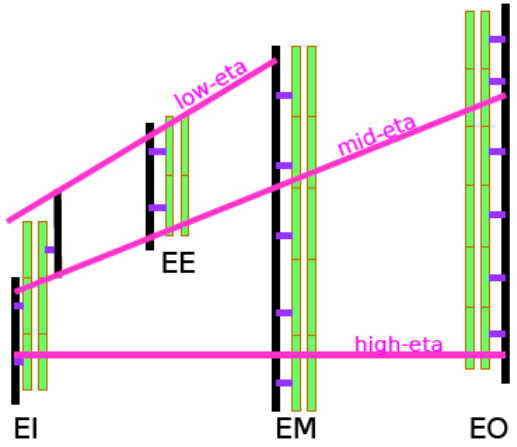
Muon alignment system



The support structures in our air-core toroid are light enough that the relative alignment of the Muon stations changes with time (e.g.: turning on/off the magnets, temperature variations – effects ~ 0.1 – 1 mm)



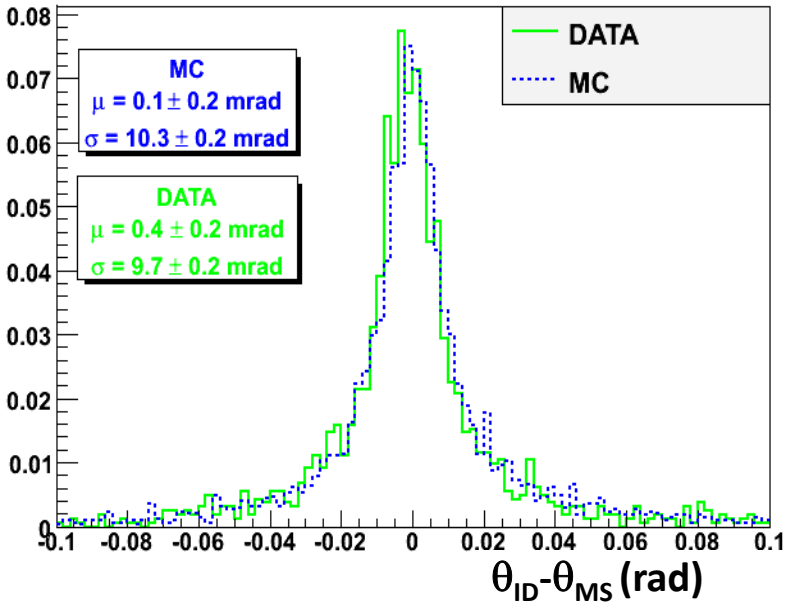
Need alignment system (optical devices, calibrated and accurately positioned on chambers to determine the geometry of the spectrometer.

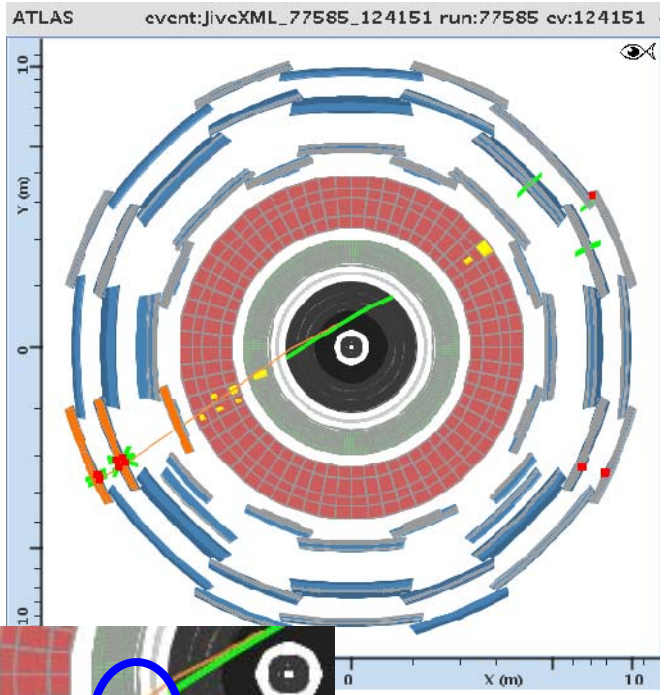


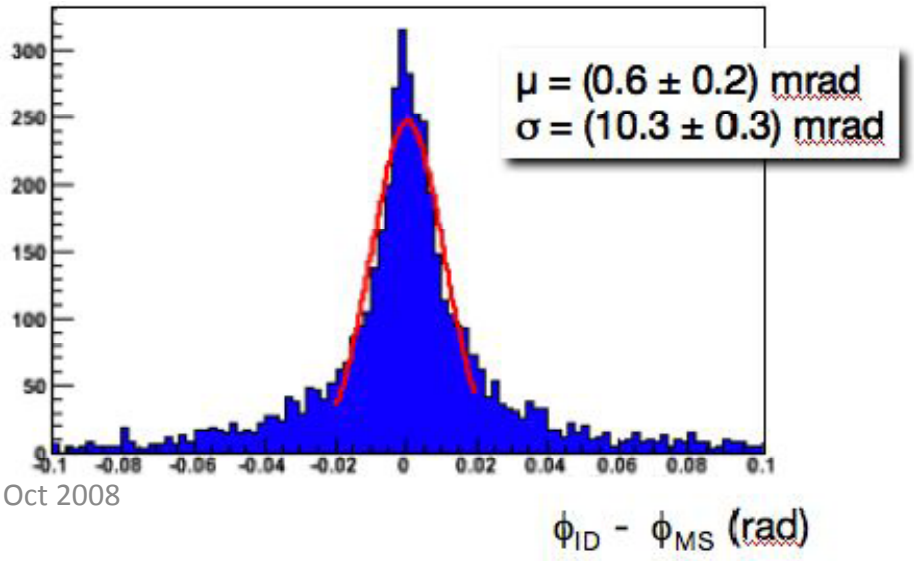
Barrel: limitations in positioning accuracy and calibration requires that the alignment system will be used in **relative mode**, referred to alignement data and tracks measured with **toroids off**.

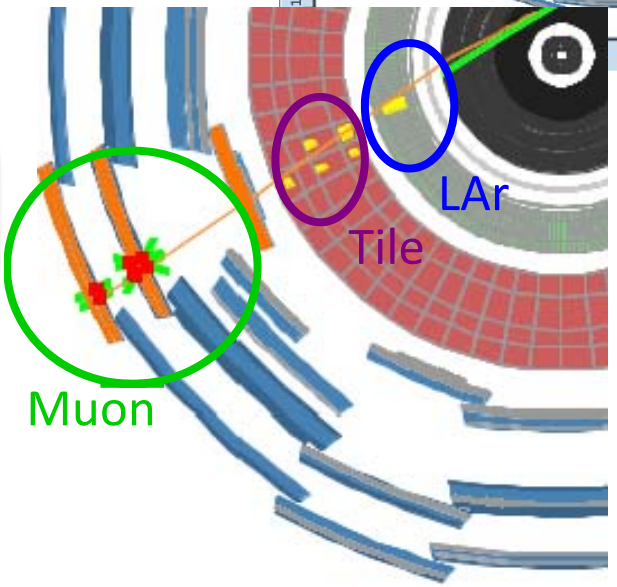
EndCap: the implementation has been accurate enough so that the geometry of the spectro-meter can be achieved from the alignment system alone **(absolute mode)** with precision as good as ~ 40 μm in the bending plane.

Combined cosmic runs



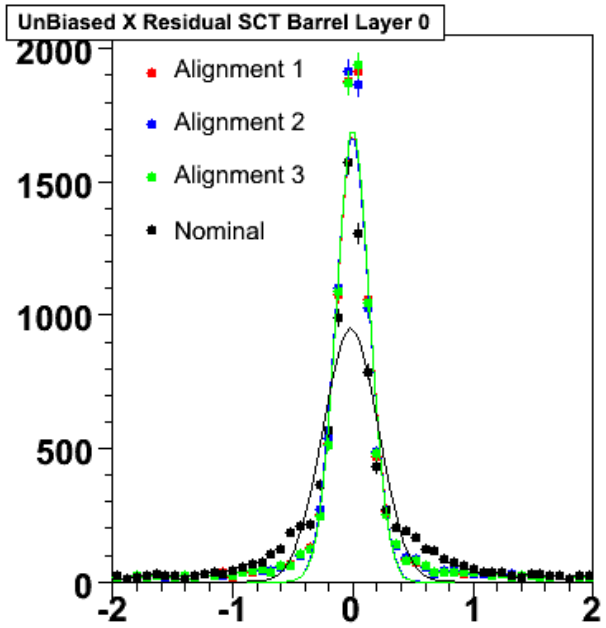




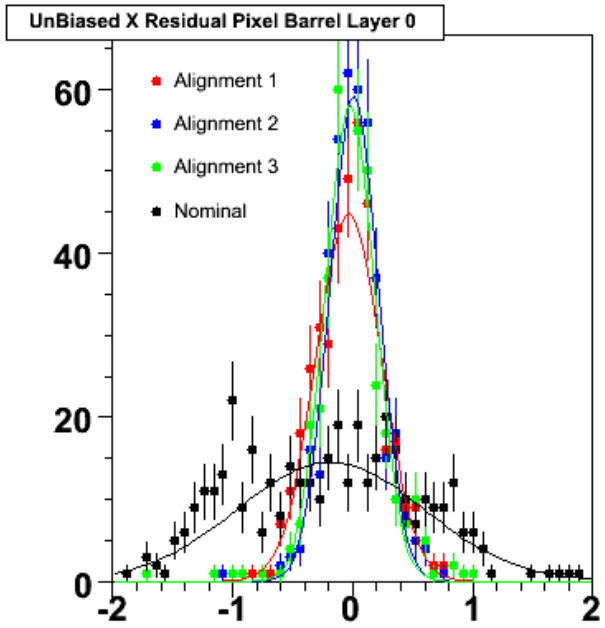


First attempts of alignment in Inner Detector

Small samples of cosmics, no B-field, no vertex cut, alignment of layers and not single modules yet, units in mm

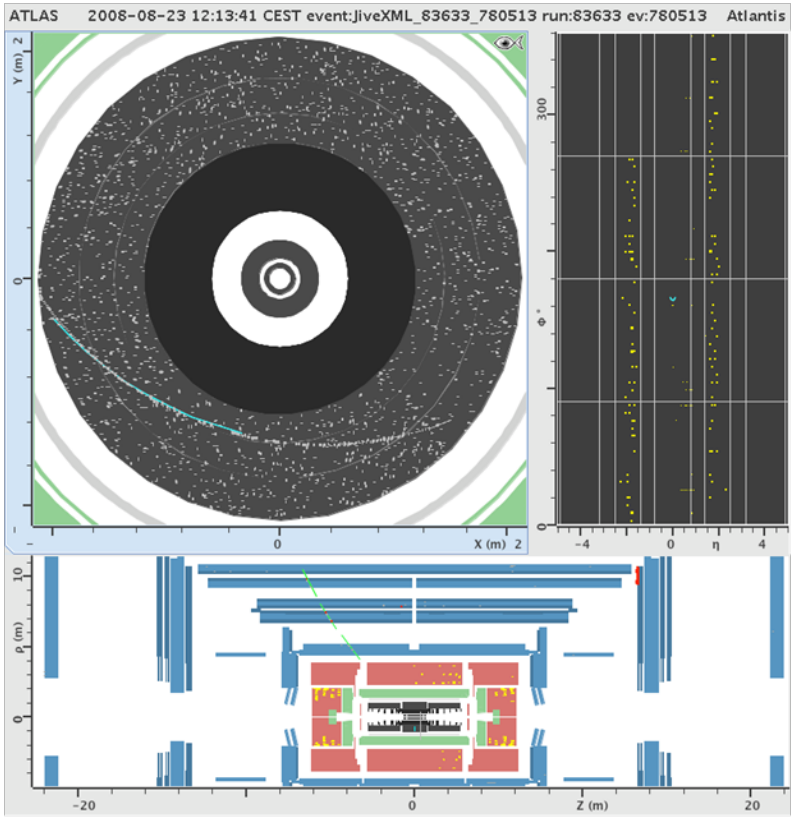


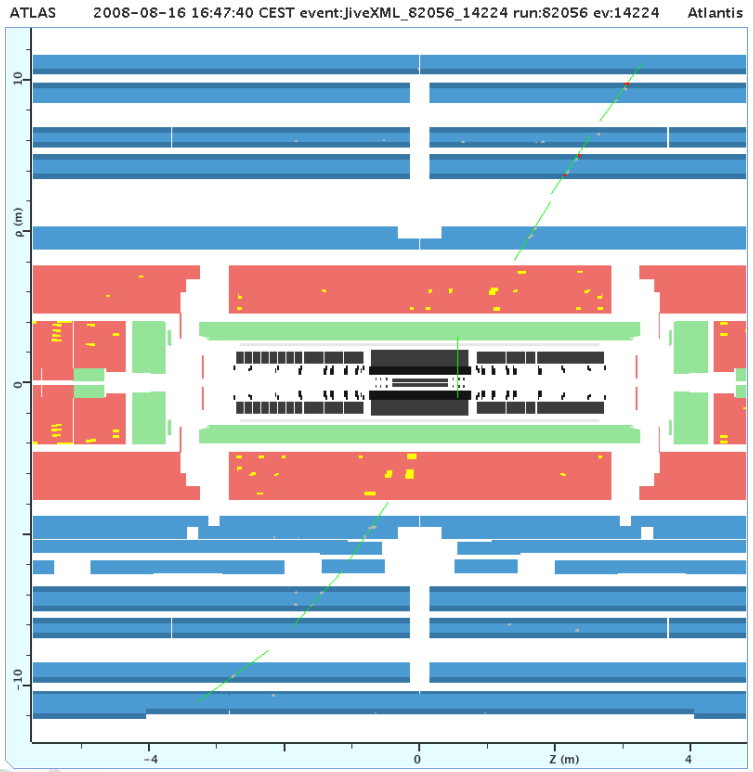
SCT alignment with small sample of cosmics, only layer-to-layer alignment

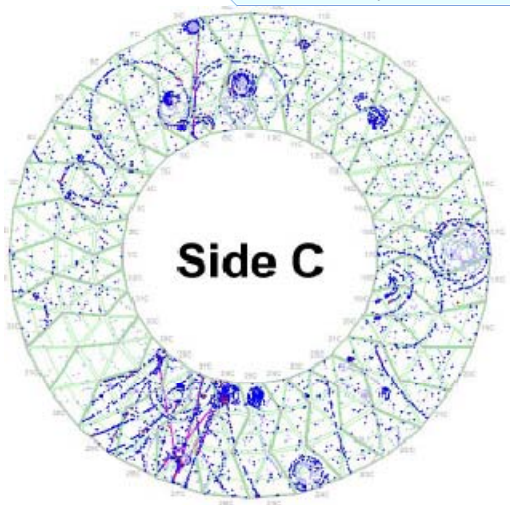


Pixel to SCT/Pixel alignment (layer-to-layer)

Cosmic events taken with magnets on

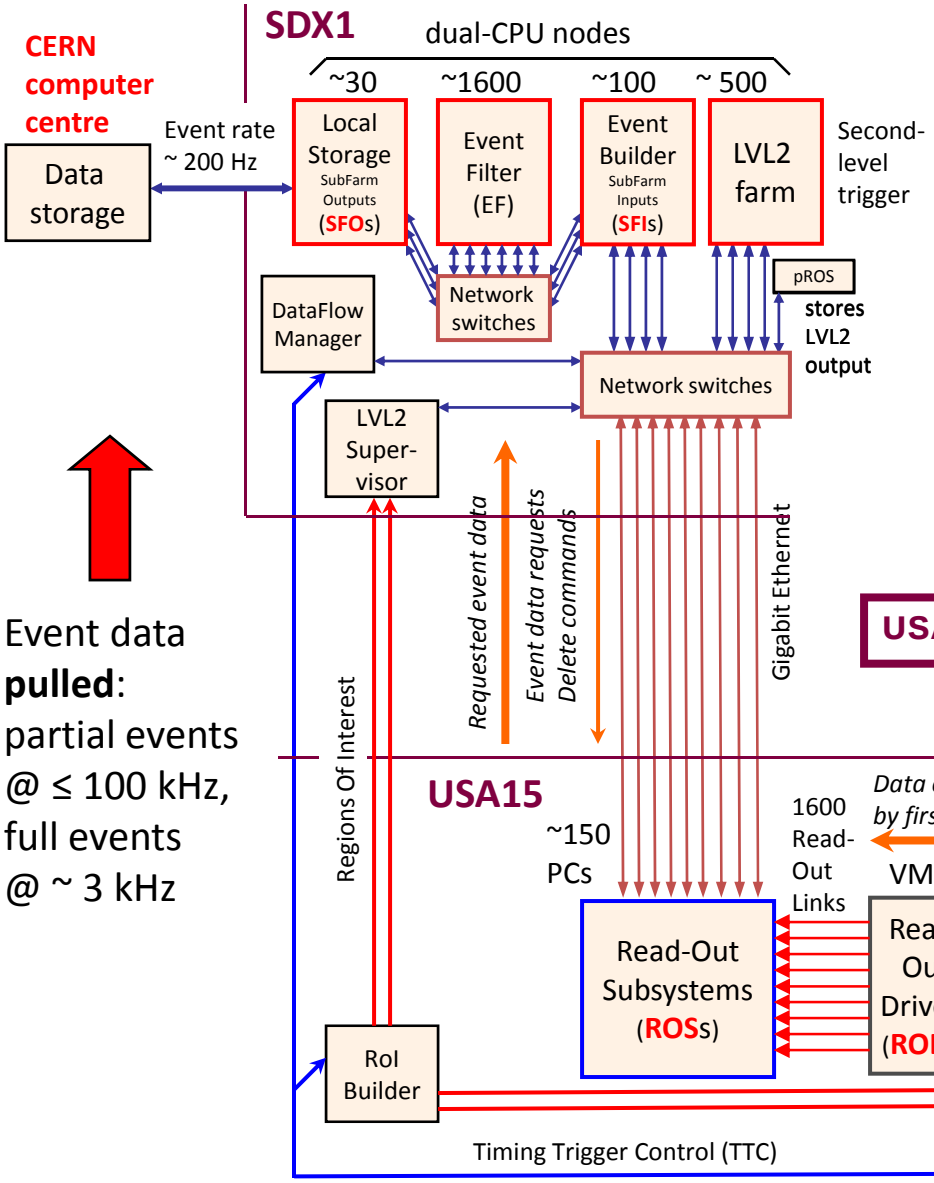


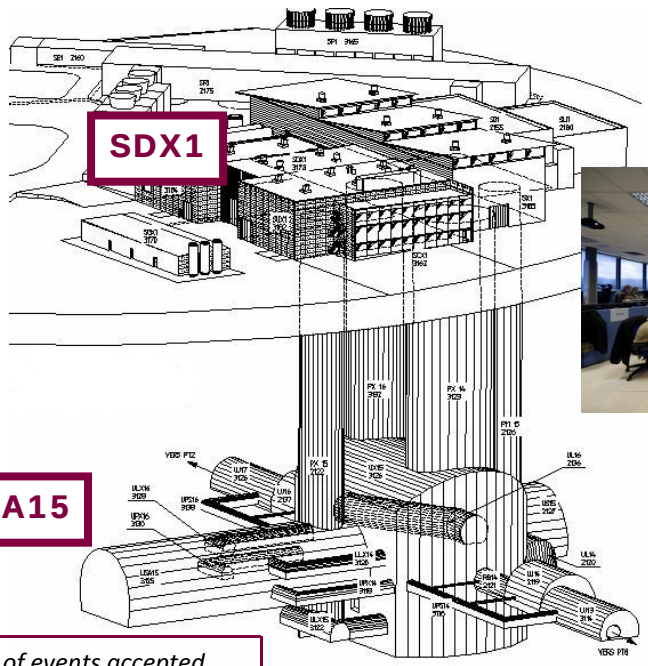


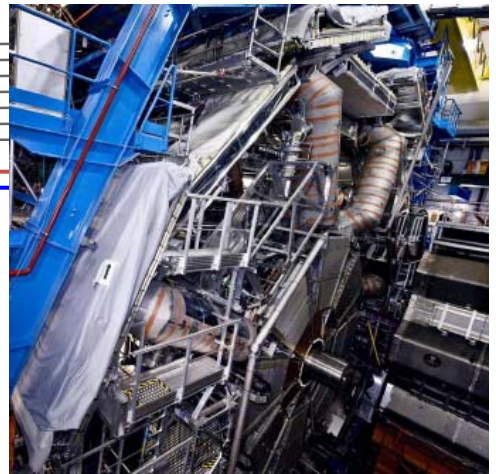


And even something like this (TRT/barrel projected to z=0):

ATLAS Trigger / DAQ Data flow







Event data **pulled**:
partial events
@ ≤ 100 kHz,
full events
@ ~ 3 kHz

Event data pushed @ ≤ 100 kHz,
1600 fragments of ~ 1 kByte each

DAQ commissioning

- DAQ/data flow system implemented and running
- Only a fraction of CPUs installed (~35%) in 2008
  - Recent result, overnight run with 10^{31} menu (800kB event*)
    - Data preloaded in 136 ROS
    - 4 L2SV - 12 L2PU racks - 94 SFIs - 10 EF racks
  - Measured
    - Lvl2 rate : 60 kHz
      - limited by RoI request rate to ROS (50% of LVL1)
      - Max expected at high luminosity is 20 kHz (20% of LVL1)
    - EB rate : 4.2kHz (LVL2 driven)
    - Aggregate effective EB bandwidth 3.3GB/s

* *Event size. Expected : 1.6 MB - normally today : 3 MB (LAr 5 samples for all cells in a cluster)*
1st-beam "splashes" : 7 MB - max seen : 13 MB (LAr 32 samples)

Commissioning of computing model

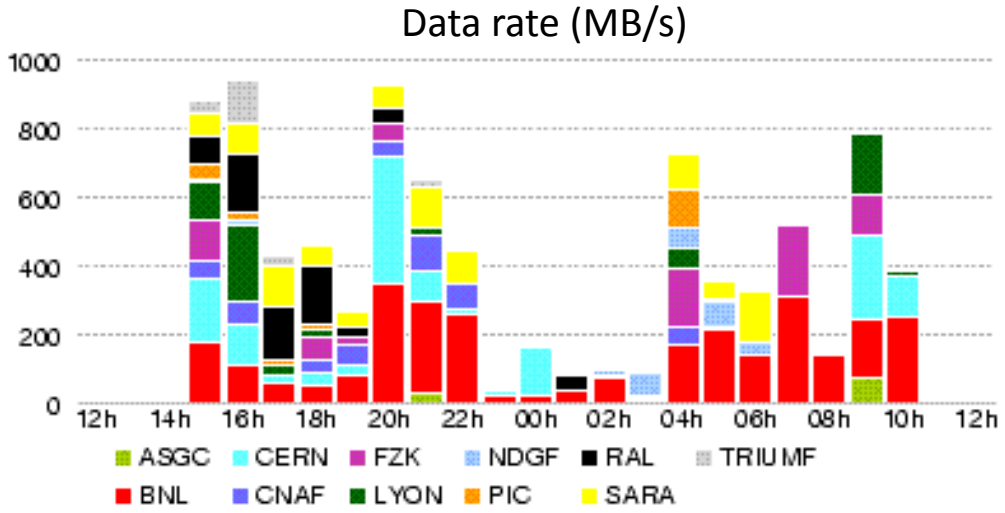
FDR I and II (Full Dress Rehearsals)

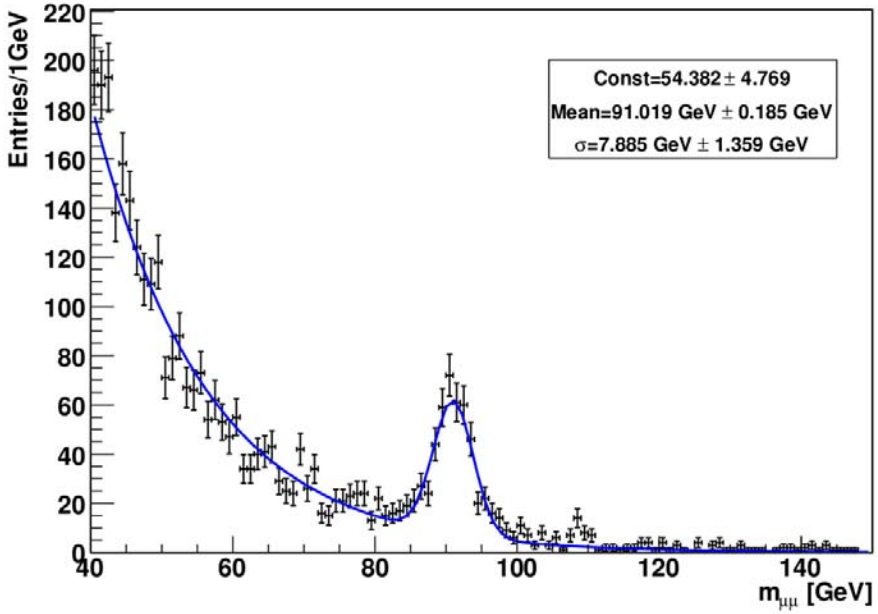
- realistic test of the computing model, from online (SFO) to analysis at Tier-2's
- all major steps included
- exercise the full & final software infrastructure (CondDB, TAGDB, trigger configuration, simulation, etc)
- implement the calibration/alignment model
- and data quality assessment
- provide samples of mixed events which look as much like data as possible for emulations of early analyses

- focused on two "FDR run weeks", each emulating a few fills of data
  - FDR-1, simulating data with $L \sim 10^{31}$ $cm^{-2}s^{-1}$
    - Feb 08, Express and bulk reconstruction, data export to Tier-1s and Tier-2s
  - FDR-2, simulating data with $L \sim 10^{32}$ $cm^{-2}s^{-1}$
    - June 08, Including calibration and alignment operation, second express stream, derived-physics-data

FDR II

RAW data export to all ten
Tier-1 sites (18h data in 19h)



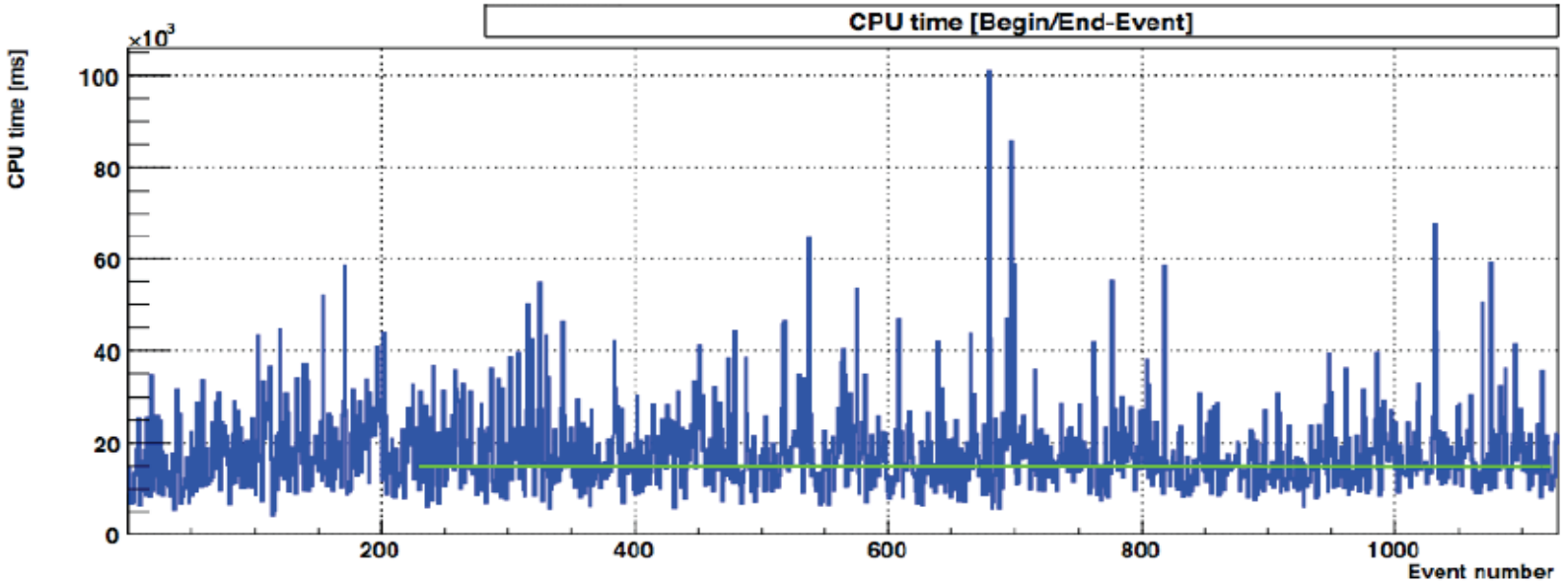


Example dimuon mass plot
made from Tier-0 DPD
(5 days after data "taken")

In summary, chain works, although
many details require more work.

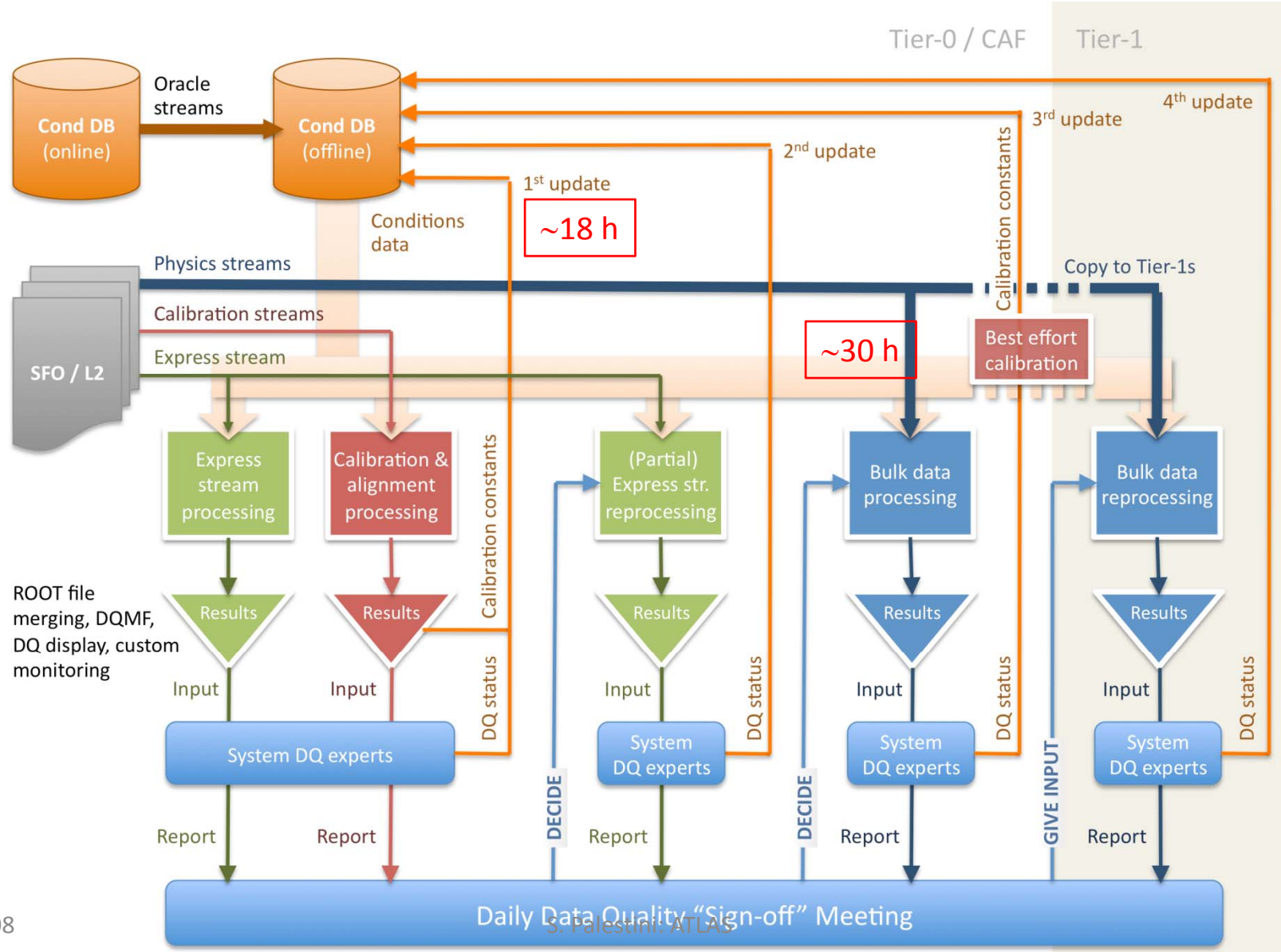
Memory and CPU for event processing

- Memory < 2 GB (=2 GB when triggers are run for simulated data)
- CPU
  - 16 kSI2k sec (FDR2b) (ESD, AOD,DPD and monitoring)(*)
  - 20% due to DPD creation (to improve) ; additional 10% overhead
  - Spikes with pile-up for 10^{33} luminosity



(*) Acronyms: EventSummaryData(output of reconstruction), AnalysisObjectData(selected output for analysis, DerivedPhysicsDatasets (further selected events/selected information)

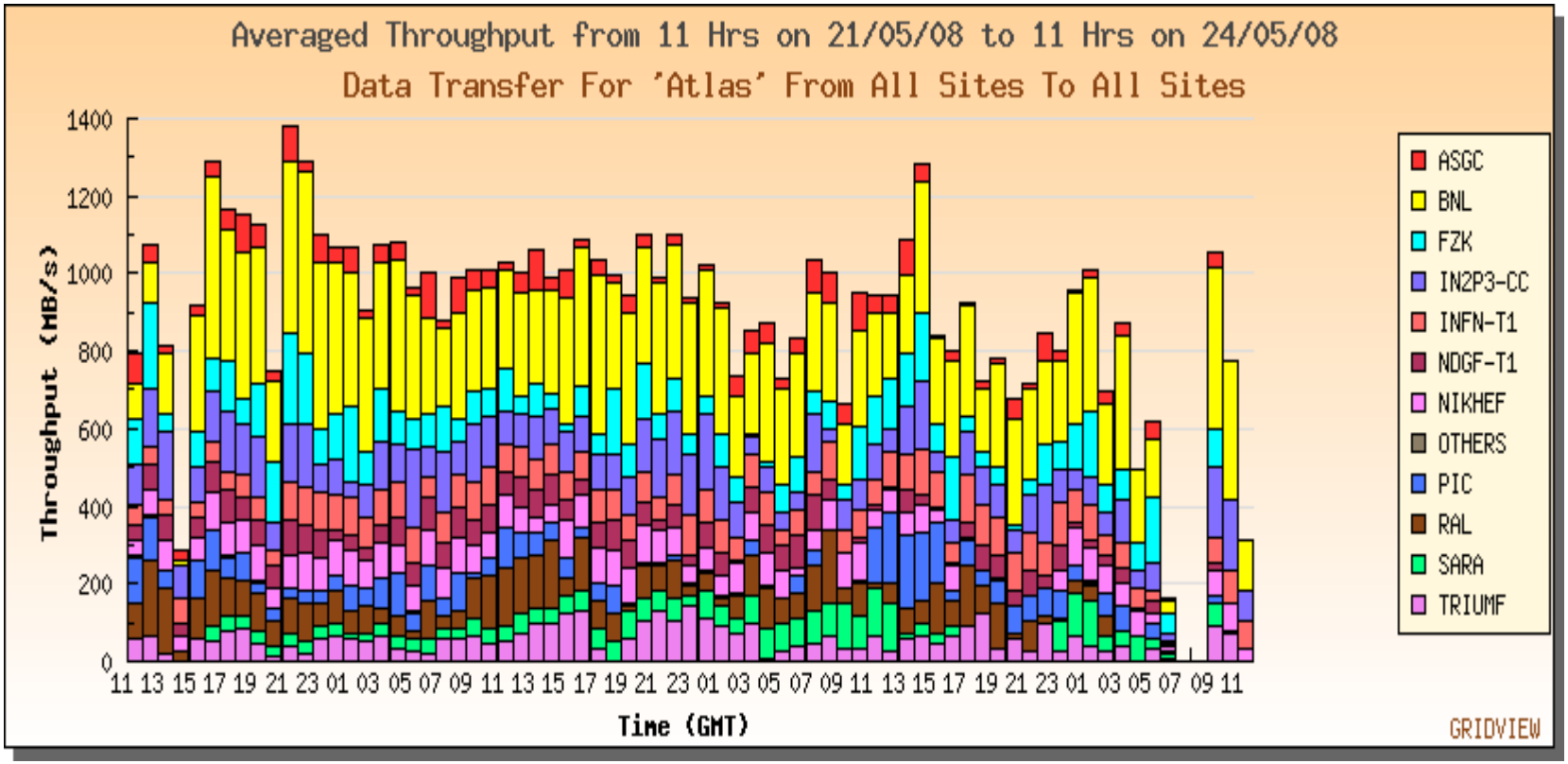
Production and calibration streams



wLCG Grid: Tier-0 and the 10 ATLAS Tier-1s

Common Computing Readiness Challenge CCRC Phase 2

Data transfer Tier-0 ⇒ Tiers-1



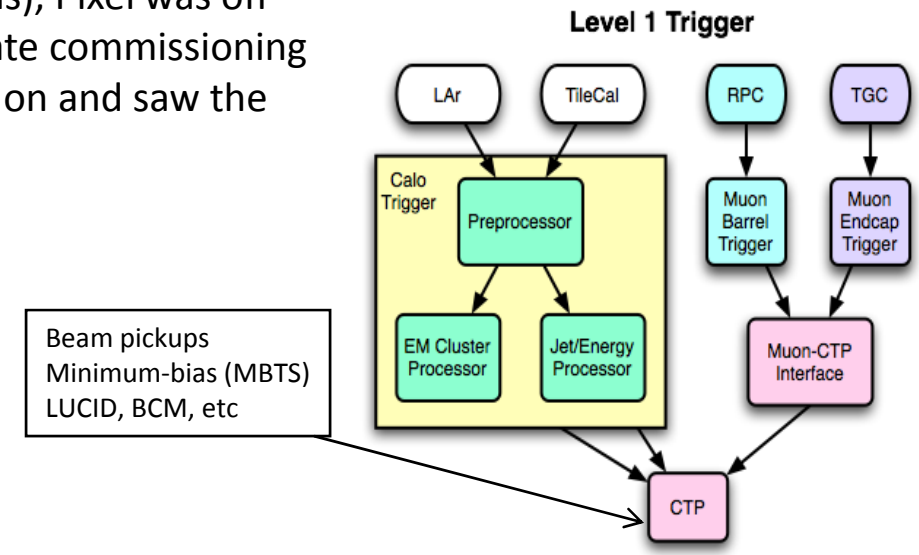
Preparation of physics studies

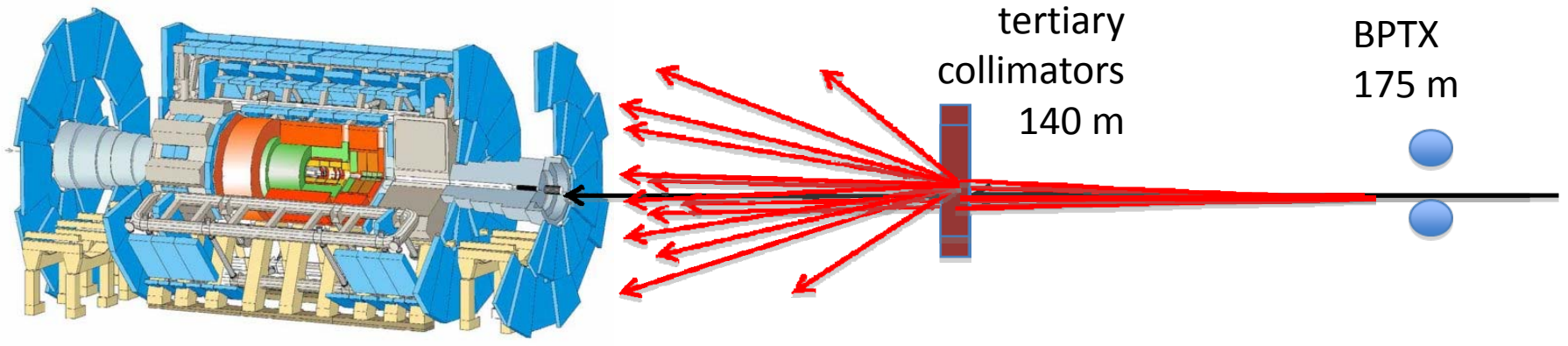
- ATLAS has recently completed a new set of physics studies, the **CSC Notes** (CSC=computer system commissioning) based on up-to-date detector description and tools for reconstruction and analysis.
- Focus on physics searches achievable with integrated luminosities in the range of ~ 10 – 100 pb^{-1}.
- Chapters cover performance studies of trigger, ID, Muon system, b-tagging, electron/photon, jets/missing E_T, and physics studies in the areas of SM, b physics, top, Higgs, SUSY, exotics.
- This effort will be published altogether as :
  - Expected performance of the ATLAS experiment, detector, trigger and physics, CERN-OPEN-2008-020 (and available on arXiv)

Detector and trigger for first LHC beams

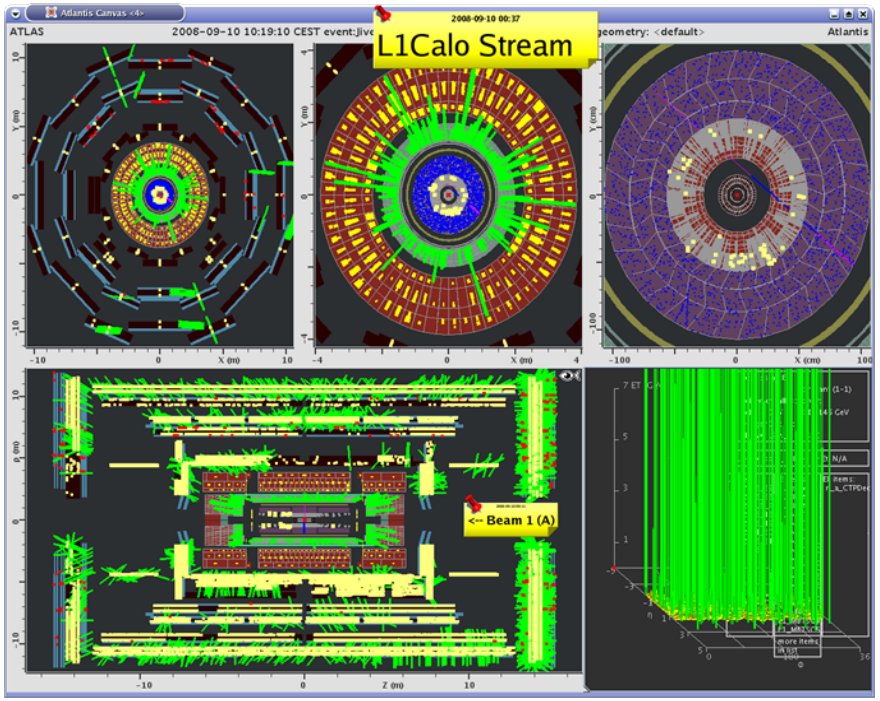
ATLAS was “on” on Sep. 10, although many components operated with reduced HV (e.g.: SCT/barrel at very low bias), Pixel was off (safety and late commissioning), CSC were off (late commissioning or read-out), the luminosity detector LUCID was on and saw the beam. The three toroid systems were on.

Level-1 triggers had been set-up using cosmic rays.
In addition, we had ready a beam-pick-up trigger (BPTX), and a dedicated scintillator hodoscope trigger (MBTS), from a device installed against the front face of the end-cap calorimeters.



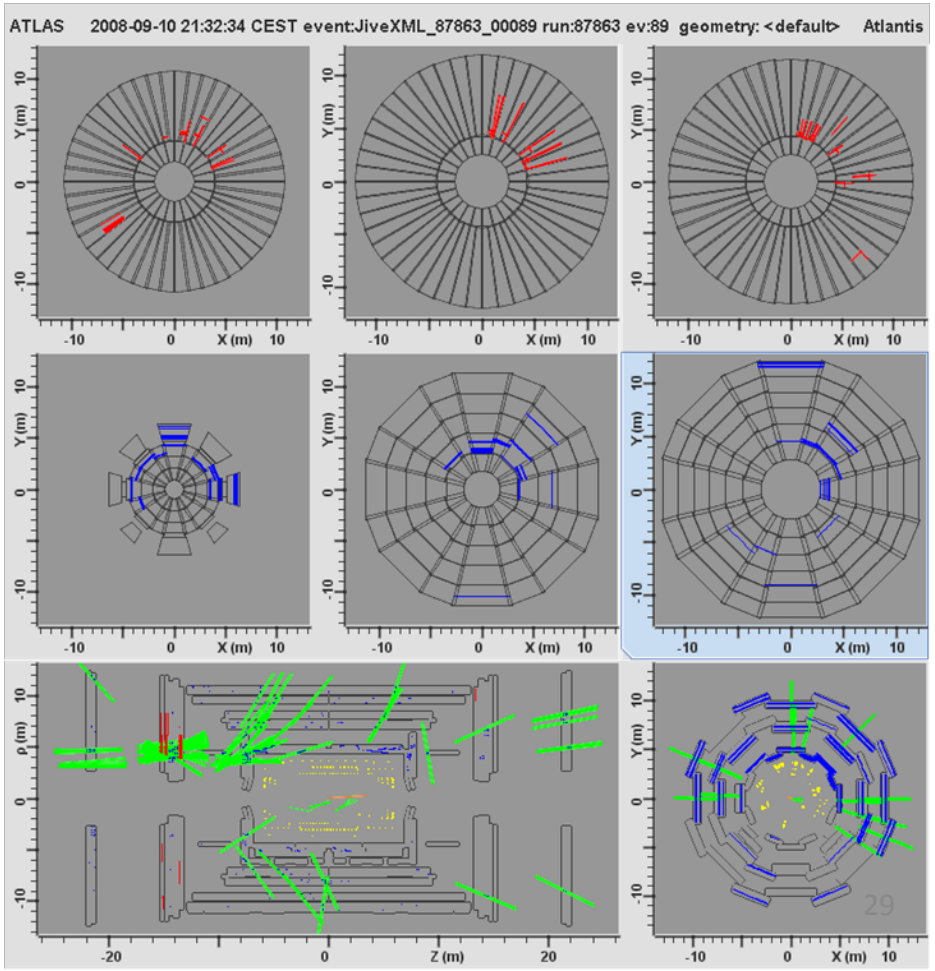


First beams from LHC on Sept. 10 - 12



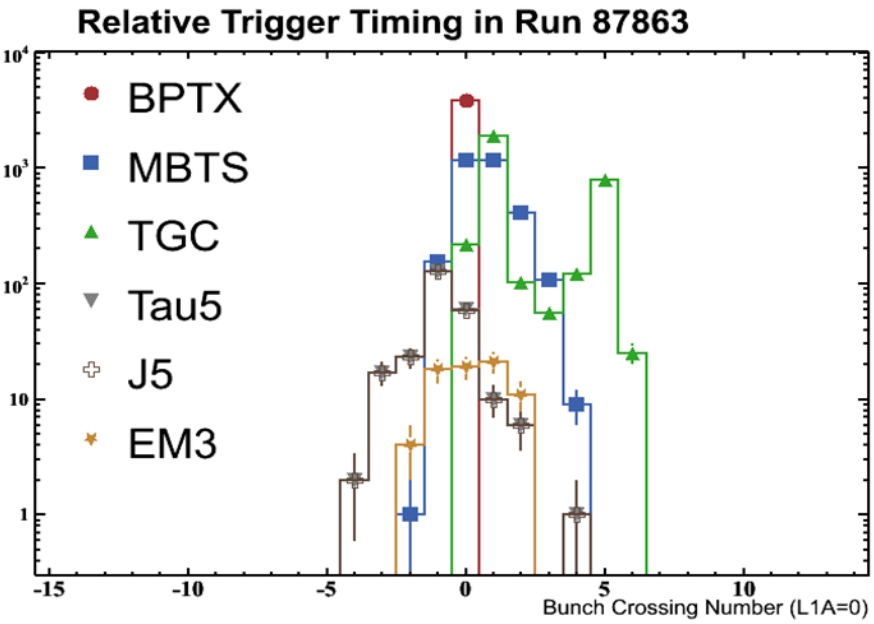
The first event recorded by ATLAS in the morning (a “splash” event, with the beam substantially dumped on collimators)

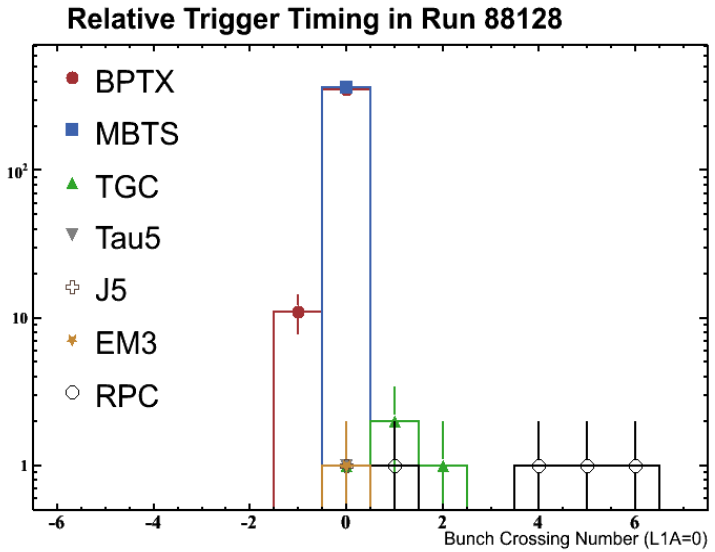
A more readable event collected later (a “halo” event, with the beam passing through the experimental area)



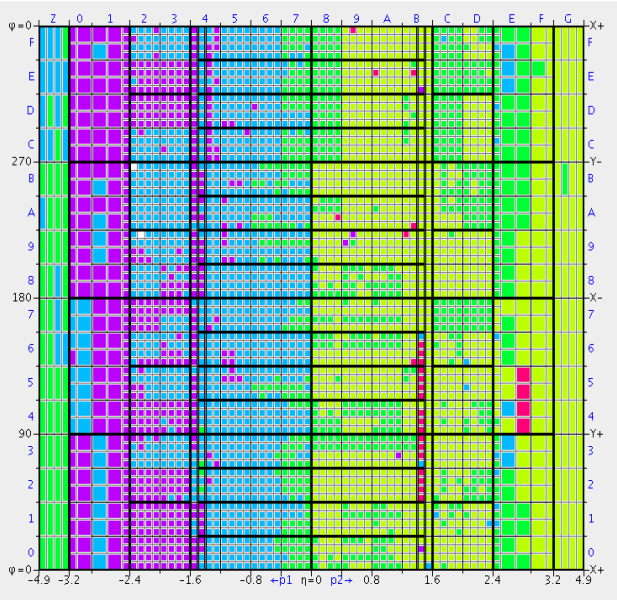
Timing of Level-1 triggers

Morning:
MPTX is the time reference. All other triggers affected by time-of-flight effects (most visible for TGC wheels – one was receiving beam from the "wrong direction")



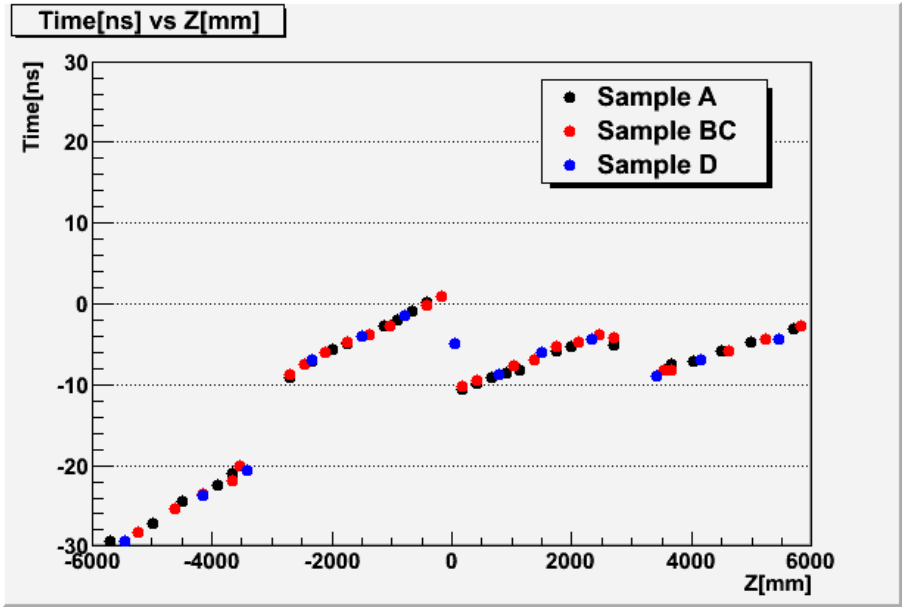


Afternoon:
fewer events, cleaner situation, time offsets better defined.



Bunch crossing units

+2
+1
0
-1
-2

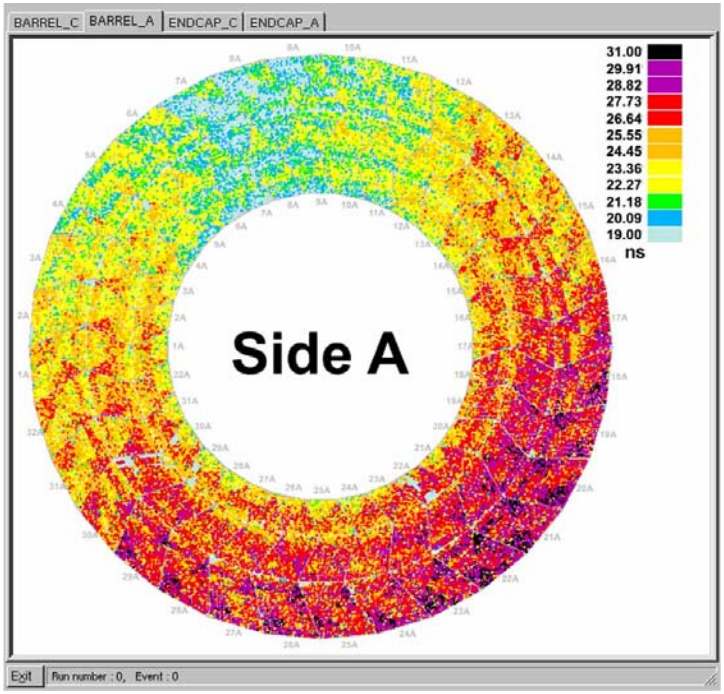


Splash events: Calorimeter trigger-towers timing vs. MPTX time:

- Some effects are instrumental,
- but time-of-flight trend due to beam is clearly visible

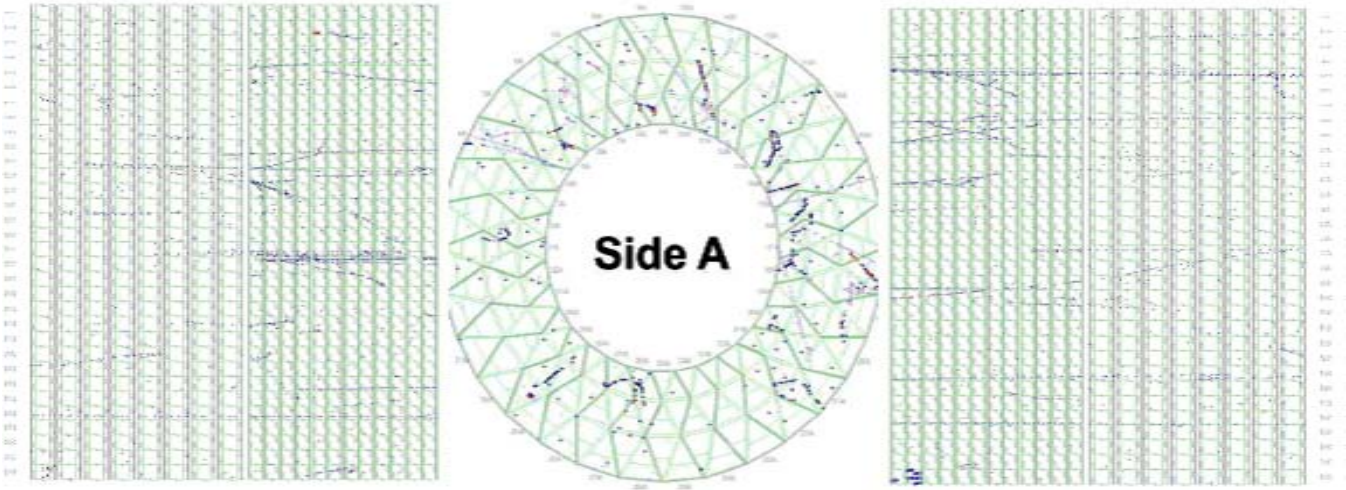
Tile-Cal timing for splash events:

- Trend within modules entirely due to time-of-flight for splash events



TRT/Barrel-A timing
from splash events

Halo event: tracks in TRT/end-caps projected on cylindrical (unrolled) surface, tracks in TRT/barrel projected on plane z=0



Conclusion

- After the impressive progress in installation and commissioning of the different subsystems in previous years, 2008 has seen a very significant progress in the overall commissioning of the detector altogether, and the ability of data handling, processing and analysis.
- Few hardware items remain to be integrated, and several software procedures have been tested successfully.
- The exercise on September 10th found us ready, and we are looking forward to collecting LHC data.

Additional ATLAS presentations at this workshop

- Nicoletta Garelli, Commissioning of the Pixel detector
- Benjamin Trocme, Commissioning and performance of the LAr calorimeter
- Danilo Banfi, Electron and photon reconstruction and identification
- Pawel Bruckman de Renstrom, Alignment of the ID
- Jose Enrique Garcia, Commissioning of the SCT
- Paul Dervan, SCT upgrade for SuperLHC
- Enrico Giulio Villani, SCT upgrade for SuperLHC
- Andrea Bocci, Commissioning of the TRT
- Zachary Marshall, ATLAS simulation software
- Christian Schmitt, Commissioning of reconstruction software
- Elena Solfaroli Camillocci, Data quality assessment in MDT calibration
- Wainer Vandelli, Readiness of Trigger and DAQ
- Jiri Masik, Trigger system in first collisions